

A bibliometric study of vascularized fibular grafting technique

 Selçuk Yılmaz

Department of Orthopaedics and Traumatology, Kütahya Health Sciences University, Turkey

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ABSTRACT

Aims: Vascularized fibula graft (VFG) technique is one of these “gold standard” techniques in bone regeneration. Although there have been several bibliometrics studies in orthopedics, there haven't been any on VFGs. By identifying the gaps in previous research, we sought to provide light on the scientific evolution of VFGs and provide direction for future investigations.

Methods: In this bibliometric study, the Web of Science (WOS) database was used to access publications on VFG published between 1986-2022. A literature search was performed with selected keywords. The dataset obtained was downloaded from the WOS database as an output. This output was analyzed with VOSviewer and Biblioshiny tools.

Results: A total of 430 documents on VFG included the study. A mean of 11.9 articles/year was published on VFG. The first article on VFG published in 1986. Since 2005, there has been an increasing trend in the number of articles and citations. The year with the highest number of both publications (n=32) and citations (n=756) was 2021. The publications on VFG have cited a total of 7300 times, an average of 16.98 citations per publication. Total 51 countries contributed to publications on the VFG between 1986-2022. The United States of America (USA) was identified as the global leader in terms of the number of publications (n=91, 21.163%), followed by Japan (n=58, 13.488%) and China (n=56, 13.023%). The USA had 91 manuscripts and 2162 citations with an H-index:29 and Japan had 58 manuscripts and 1145 citations with an H-index:22.

Conclusion: The literature on VFG is quite limited. Most of the publications are from developed countries. Studies should be supported for this method that can be used in the treatment of many diseases, especially in developing countries.

Keywords: Publications, bibliometric analysis, vascularized fibular grafting

INTRODUCTION

Bone regeneration is a complicated, well-coordinated physiological process of bone formation that is involved in ongoing remodeling throughout life and can be observed during normal fracture repair.^{1,2}

There are many methods that are considered the “gold standard”: For example, autologous bone grafting, allograft implantation, and the use of growth factors, osteoconductive scaffolds, osteoprogenitor cells, and distraction osteogenesis are just some of the current techniques used to improve the impaired or “inadequate” bone regeneration process. Vascularized fibula graft (VFG) is one of these “gold standard” techniques.³

VFGs, in contrast to other bone-grafting techniques, call for the preservation and reconnection of a vascular pedicle from the donor site to the graft site.⁴

Vascularized fibula graft transfer technique is a well-known technique for treating large bone abnormalities brought on by infection, tumor excision, early stages of osteonecrosis, or trauma.^{4,5} It avoids the creeping substitution process that traditional bone transplants

go through, resulting in better recovery and increased strength.⁴ Also free VFG is a biological reconstruction technique that can promote the growth of new bone and nourish the cartilage in the femoral head's subchondral region.⁶

The VFG technique dates back to the 1960s, but its first applications began after microvascular anastomosis procedures were developed.⁴ Taylor et al.⁷ reported the first case study describing the VFG technique in the year 1975. In this report, a tibial defect was repaired utilizing a vascularized graft from the opposing fibula.⁵ Since then, the indications for VFG have grown to include fixing skeletal defects brought on by trauma, congenital pseudoarthrosis, tumors, and infections.^{4,8,9} VFG recipient sites can be upper or lower extremities and this technique can be used in both adult and pediatric patients.⁴

Intensive scientific research is being conducted in tissue engineering and gene therapy to reduce the disadvantages of the latest methods, to develop bone graft implants with biomechanical properties as similar as possible to normal bone structure, and to accelerate the bone regeneration process.²

Corresponding Author: Selçuk Yılmaz, dryilmazselcuk@gmail.com



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Bibliometric studies are research methods that examine the results of scientific outputs in a field of science or research topic and guide further studies. With this technique, which is used in many fields including medicine, many scientific advances and gaps can be identified.¹⁰⁻¹⁷ Although many studies have been conducted in orthopedics, no similar study was found in the literature on VFGs.^{18,19} In this bibliometric study, our aim was to reveal the scientific development of VFGs and to guide future studies by identifying the missing points.

METHODS

The study is an open data bibliometric study, does not contain human or animal material, and does not require ethics committee approval, and informed consent. All procedures were carried out in accordance with the ethical rules and the principles.

This study is a bibliometric study of the literature on vascularized fibular grafting technique. In this study, the Web of Science (WOS) electronic bibliometric database was used to access publications on the relevant topic.

As the WOS database is constantly updated, we conducted a literature search in the WoS database on a single day, February 15, 2023.

Inclusion/Exclusion Criteria

We adopted a comprehensive search strategy to access VFG's publication records. Language, country/region were not applied. Since the first publication was published in 1986, we chose 1986 as the search start year. Since 2023 was not completed, we did not include publications in 2023. In summary, we chose 1986-2022 as the search years. We did not exclude by document type. In addition,

publications in all sub-indexes of the WOS core collection were included in the study.

Search Terms

A literature search was performed with selected keywords (vascularized fibular graft OR vascularized fibular grafting OR Vascularized Fibular Bone Grafting) in the TITLE section of the WOS database search engine.

Bibliometric Methods and Visualization Tools

Then, the dataset obtained was downloaded from the WOS database as an output. This output was transferred to Excel 2019, VOSviewer_1.6.18 visualization tool, and an open-source data visualization software tool Biblioshiny (version 2.0) were used to examine the development and trends in article themes.²⁰

Bibliometric data such as countries with the highest number of publications in the relevant subject, types of publications, number of publications over the years, number of citations, institutions where the most publications were published, authors who published the most publications, trending topics, dominant keywords of publications were analyzed. In addition, detailed visualization of collaborations between countries was made using Vos viewer.

RESULTS

A total of 430 documents on VFG published until the end of 2022 were selected and included in the analysis. A mean of 11.9 articles/year was published on VFG. The first article on VFG published in 1986. The development of VFG's publications over time is depicted in **Figure 1** together with citations. A general upward trend in publications was observed, with small downward fluctuations in some years.

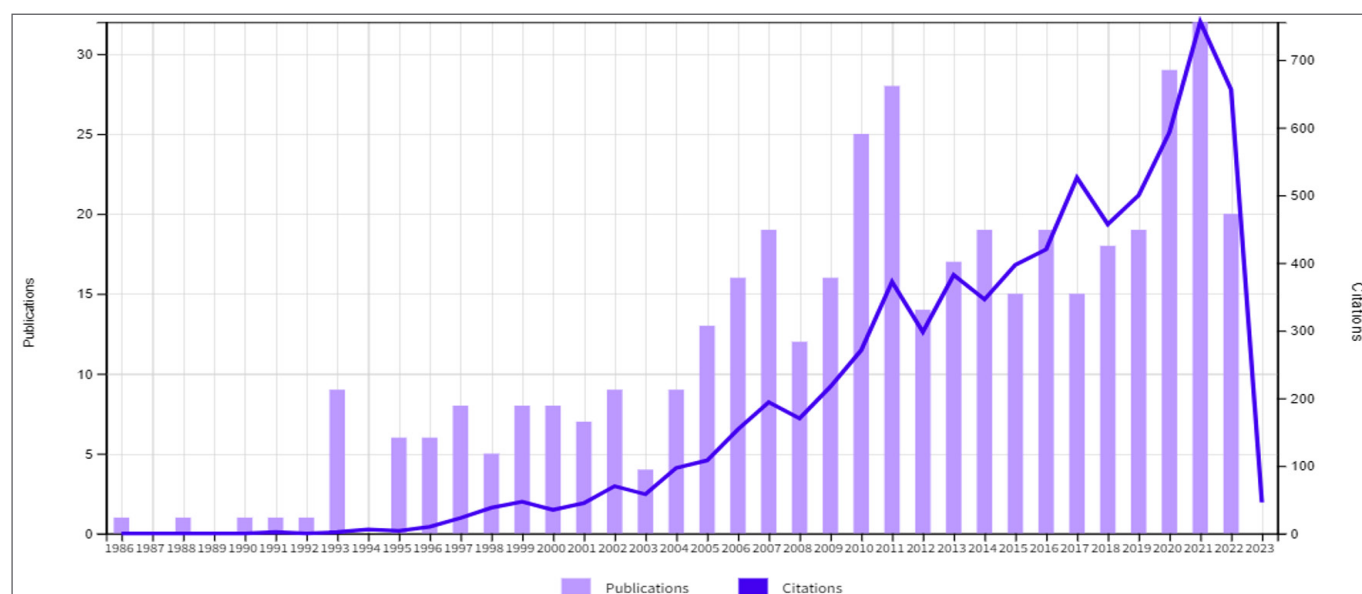


Figure 1. Annual publication and citation numbers of the VFG publications between 1986-2022*

* Downloaded from the WoS database. Although the research year is until the end of 2022, 2023 is also seen in this dataset. 2023 citation numbers are not yet calculated in WoS as the year is not over.

Since 2005, there has been an increasing trend in the number of articles. 2021 is the year with the highest number of publications with 35 publications (7.442%). Since 2013, at least 15 publications have been published every year (**Figure 1**). The annual number of citations of VFG publications is irregular but has never fallen below 100 per year since 2005 (**Figure 1**). The year with the highest number of both publications (n=32) and citations (n=756) was 2021. In 2022, there was a decrease in the number of publications (n=20) and citations (n=656) (**Figure 1**).

95.814% of the publications were in English. 85.349% were indexed in Science Citation Index Expanded (SCI-EXPANDED), 12.558% in Emerging Sources Citation Index (ESCI), 4.651% in Conference Proceedings Citation Index - Science (CPCI-S) and 1.163% in Book Citation Index - Science (BKCI-S). The publications on VFG have cited a total of 7,300 times, an average of 16.98 citations per publication. The average value of the H indexes was 45.

Total 51 countries contributed to publications on the VFG between 1986-2022. The United States of America (USA) was identified as the global leader in terms of the number of publications (n=91, 21.163%), followed by Japan (n=58, 13.488%) and China (n=56, 13.023%) (**Table 1**). The USA contributed 91 manuscripts and 2162 citations with an h-index of 29 and 23.76 citations per publication in the VFG from 1986 to 2022. Japan contributed 58 manuscripts and 1145 citations with an H-index of 22 and 19.74 citations per publication in the VFG in the same period.

Table 1. Countries with the most publications on VFG between 1986 and 2022

Ranking	Countries/Regions	n	%
1	Usa	91	21.163
2	Japan	58	13.488
3	China	56	13.023
4	France	32	7.442
5	Italy	30	6.977
6	India	24	5.581
7	Egypt	20	4.651
8	England	19	4.419
9	Germany	17	3.953
10	Turkey	15	3.488
11	Australia	10	2.326
12	Greece	10	2.326
13	Switzerland	10	2.326
14	Netherlands	7	1.628
15	Pakistan	7	1.628
16	Spain	7	1.628
17	Taiwan	7	1.628
18	Singapore	6	1.395
19	South Korea	6	1.395
20	Austria	5	1.163
21	Canada	5	1.163
22	Indonesia	5	1.163
23	Israel	4	0.930
24	Brazil	3	0.698
25	Iran	3	0.698

*Showing 25 out of 51 countries; no data about 1 record

The publications on VFG were published in 25 research areas, the most common being surgery (63.023%) and orthopedics (52.326%). Some publications were published in more than one research area (**Table 2**).

Table 2. Top research areas of the VFG publications

Research Areas	n	% of 430
Surgery	271	63.023
Orthopedics	225	52.326
General internal medicine	31	7.209
Oncology	30	6.977
Pediatrics	21	4.884
Neurosciences neurology	12	2.791
Dentistry oral surgery medicine	11	2.558
Emergency medicine	10	2.326
Research experimental medicine	9	2.093

There was 430 documents and 359 articles on VFG published between 1986-2022. 1665 authors contributed the VFG literature. Annual growth rate of the publications was 3.01.

%14 documents were single-authored. International co-authorships rate was %11.83. Main information on VFG literature is given in **Table 3**.

Table 3. Main information on VFG literature published between 1986-2022.

Description	Results
Timespan	1986-2022
Sources (journals, books, etc)	145
Documents	430
Annual growth rate %	3.01
Document average age	11.9
Average citations per doc	16.93
References	6073
Document contents	
Keywords plus (ID)	625
Author's keywords (DE)	691
Authors	
Authors	1665
Authors of single-authored docs	14
Authors collaboration	
Single-authored docs	14
Co-authors per doc	4.94
International co-authorships %	11.83
Document types	
Article	359
Book chapter	5
Early access	2
Proceedings paper	15
Editorial material	5
Letter	1
Meeting abstract	1
Proceedings paper	5
Review	38

The publications were published in 146 different journals. The journals with the most publications on VGF were the Journal of bone and joint surgery (n=22), Microsurgery (n=22), and Journal of Reconstructive Microsurgery (n=20). **Table 4** summarizes the journals that publish the most on VGF.

Publication Titles	n	%	Journal impact factor (five year)
Journal of Bone and Jointsurgery British Volume	22	5.116	3.479
Microsurgery	22	5.116	2.405
Journal of Reconstructive Microsurgery	20	4.651	2.492
Clinical Orthopaedicsand Related Research	17	3.953	5.885
Journal of Bone and Jointsurgery American Volume	16	3.721	6.955
Journalofhand Surgeryamerican Volume	12	2.791	2.809
Journal of Plastic Reconstructive and Aesthetic Surgery	12	2.791	3.215
Orthopaedics Traumatology Surgery Research	11	2.558	2.847
Plasticand Reconstructive Surgery	11	2.558	5.348
Annalsofplastic Surgery	10	2.326	1.988

The authors from 550 affiliations contributed the VGF research. The authors with the most publications in the VFG were affiliated with institutions in the USA. Mayo Clinic from the USA was the most productive affiliation on VGF research with 32 publications. Sapporo Medical

University from Japan ranked 2nd with 11 publications and followed by Duke University from the USA (n=10), the University of Pennsylvania from the USA (n=10) and the University of California, Davis (UC Davis, UCD, or Davis) from the USA (n=9). The number of publications of institutions according to years is schematized in **Figure 2**.

The article published by Capanna and colleagues in Orthopedic Clinics of North America in 2007 was the most cited article on VFG (n=148 and with an average of 8.71 citations per year).²¹ The summary list of the top 25 most cited articles on VFG published between 1986 and 2022 is given in **Table 5**.

Figure 3a and **Figure 3b** provide an overview of the use of these keywords and present a chronological analysis of the keywords provided by the article's writers. Three distinct periods were separated from the life span in order to calculate the frequency of keywords throughout time. The term "resection" was used in the most research (n=108). These studies also received the most citations after they were published. The majority of articles containing this term were published after 2000s. The second most common term over the past 20 years has consistently been "reconstruction," and it is also the most utilized keyword. 'Graft', 'defects', 'flap', 'osteosarcoma', 'bone', 'vascularized fibular graft', 'tumor resection', 'management', 'allograft', 'children', and 'replacement' are other noteworthy keywords in terms of their frequency of occurrence during the last ten years. **Figure 3c** is the keyword frequency tree.

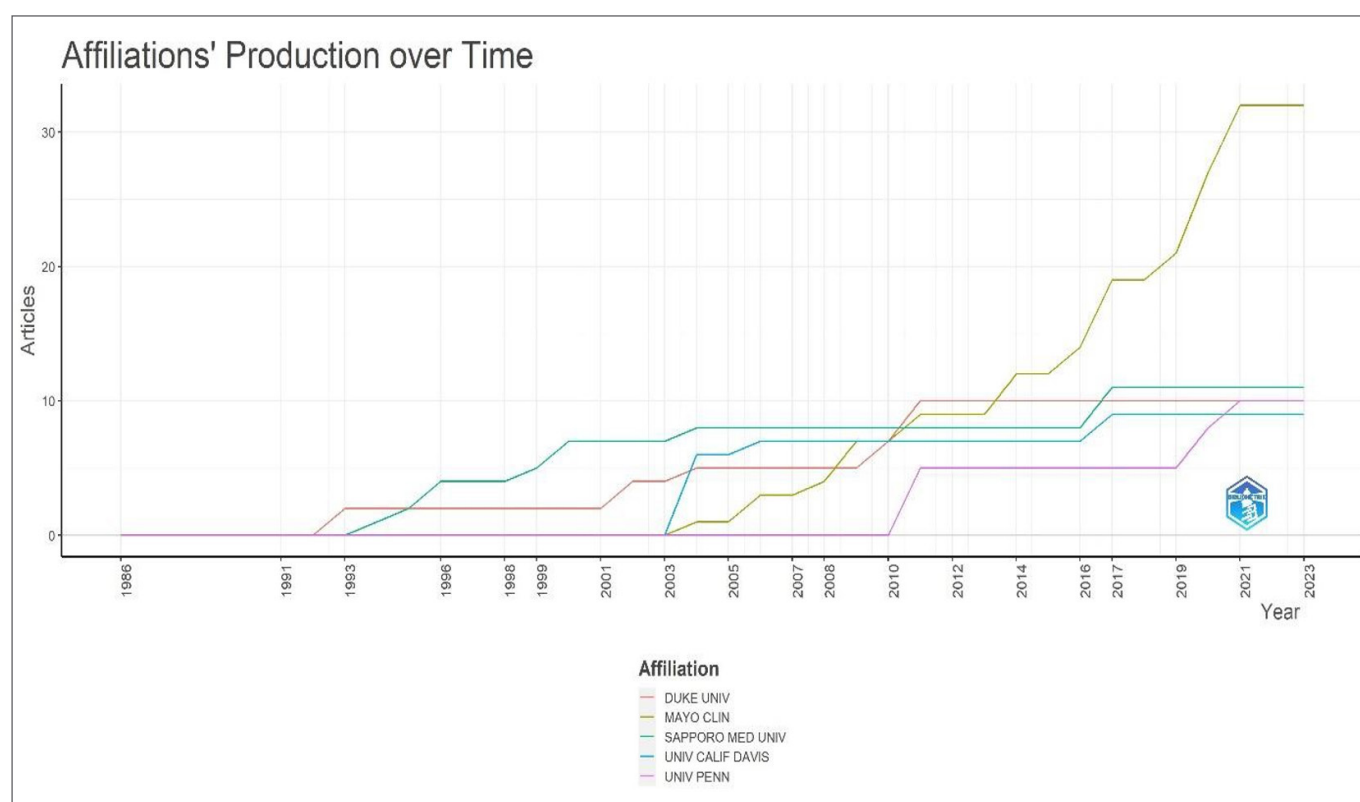


Figure 2. Annual production of mostly publishing affiliations on VFG

Table 5. Summary list of the top 25 most cited manuscripts on VFG published between 1986 and 2022

Ranking	Title	Authors	Source Title	Publication Year	DOI	Total citations	Average per year
1	A new reconstructive technique for intercalary defects of long bones: the association of massive allograft with vascularized fibular autograft. Long-term results and comparison with Alternative techniques	Capanna, et al.	Orthopedic Clinics of North America	2007	10.1016/j.joc.2006.10.008	148	8.71
2	Limb salvage for neoplasms of the shoulder girdle - intermediate reconstructive and functional Results	O'Connor, et al.	Journal of Bone and Joint Surgery- American Volume	1996	10.2106/00004623- 199612000-00011	137	4.89
3	Free vascularised fibular grafting for reconstruction After tumour resection	Hsu, et al.	Journal of Bone and Joint Surgery- British Volume	1997	10.1302/0301- 620X.79B1.6818	119	4.41
4	Arthrodesis of the ankle with a free vascularized autogenous bone graft-reconstruction of segmental loss of bone secondary to osteomyelitis, Tumor, or trauma	Bishop, et al.	Journal of Bone and Joint Surgery- American Volume	1995	10.2106/00004623- 199512000-00011	97	3.34
5	The use of massive bone allograft with intramedullary free fibular flap for limb salvage in a pediatric and adolescent Population	Moran, et al.	Plastic and Reconstructive Surgery	2006	10.1097/01.prs.0000227682.7 1527.2b	95	5.28
6	Free vascularized fibular grafts for reconstruction of skeletal defects	Malizos, et al.	Journal of The American Academy of Orthopaedic Surgeons	2004	10.5435/00124635- 200409000-00010	92	4.6
7	Vascularized fibula transfer for lower Limb Reconstruction	Beris, et al.	Microsurgery	2011	10.1002/micr.20841	89	6.85
8	The use of free fibular flap for functional mandibular Reconstruction	Peled, et al.	Journal of Oral and Maxillofacial Surgery	2005	10.1016/j.joms.2004.06.052	84	4.42
9	Precision tumour resection and reconstruction using image- Guided computer navigation	Wong, et al.	Journal of Bone and Joint Surgery- British Volume	2007	10.1302/0301- 620X.89B7.19067	79	4.65
10	Vascularized proximal fibular epiphyseal transfer for distal radial Reconstruction	Innocenti, et al.	Journal of Bone and Joint Surgery- American Volume	2004	10.2106/00004623- 200407000-00021	71	3.55
11	Vascularized fibular graft after excision of giant- cell tumor of the distal radius: wrist arthroplasty Versus partial wrist arthrodesis	Minami, et al.	Plastic and Reconstructive Surgery	2002	10.1097/00006534- 200207000-00020	70	3.18
12	The treatment of giant- cell tumors of the distal part of the Radius	Vandergrie, et al.	Journal of Bone and Joint Surgery- American Volume	1993	10.2106/00004623- 199306000-00011	69	2.23
13	Technical procedures for template-guided surgery for mandibular reconstruction based on digital Design and manufacturing	Liu, et al.	Biomedical Engineering Online	2014	10.1186/1475-925X-13-63	68	6.8
14	Vascularized fibular grafts for reconstruction of the femur	Yajima, et al.	Journal of Bone and Joint Surgery- British Volume	1993	10.1302/0301- 620X.75B1.8421008	67	2.16
15	Treatment of segmental defects of the humerus with an osteoseptocutaneous fibular transplant	Heitmann, et al.	Journal of Bone and Joint Surgery- American Volume	2002	10.2106/00004623- 200212000-00014	61	2.77
16	Vascularized free fibular transfer combined with autografting for the management of fracture nonunions Associated with radiation therapy	Duffy, et al.	Journal of Bone and Joint Surgery- American Volume	2000	10.2106/00004623- 200004000-00009	60	2.5
17	Reconstruction and limb salvage after resection for malignant bone tumour of the proximal humerus - a Sling procedure Using a free Vascularised fibular graft	Wada, et al.	Journal of Bone and Joint Surgery- British Volume	1999	10.1302/0301- 620X.81B5.9430	59	2.36
18	Free vascularized fibular graft reconstruction of large skeletal Defects after tumor resection	Eward, et al.	Clinical Orthopaedics and Related Research	2010	10.1007/s11999-009-1053-x	58	4.14
19	Long bone reconstruction with vascularized Bone grafts	Pederson, et al.	Orthopedic Clinics of North America	2007	10.1016/j.joc.2006.10.006	58	3.41
20	Methods of reconstruction for bone defect after tumor excision: a review of Alternatives	Nishida, et al.	Medical Science Monitor	2008		56	3.5
21	Free vascularized fibular graft salvage of complications of long-bone allograft after tumor Reconstruction	Friedrich, et al.	Journal of Bone and Joint Surgery- American Volume	2008	10.2106/JBJS.G.00551	56	3.5
22	Reconstruction of large posttraumatic skeletal defects of the forearm by Vascularized free fibular graft	Adani, et al.	Microsurgery	2004	10.1002/micr.20067	56	2.8
23	Intercalary segmental reconstruction of long bones after malignant bone tumor resection using primary methyl methacrylate cement spacer interposition and secondary bone grafting: the induced membrane Technique	Villemagne, et al.	Journal of Pediatric Orthopaedics	2011	10.1097/BPO.0b013e31821ff a82	55	4.23
24	Hypertrophy after free vascularized fibular transfer to The lower limb	El-Gammal, et al.	Microsurgery	2002	10.1002/micr.10066	54	2.45
25	Vascularized fibular graft for bone reconstruction of the extremities after tumor resection In limb-saving procedures	Minami, et al.	Microsurgery	1995	10.1002/micr.1920160204	54	1.86

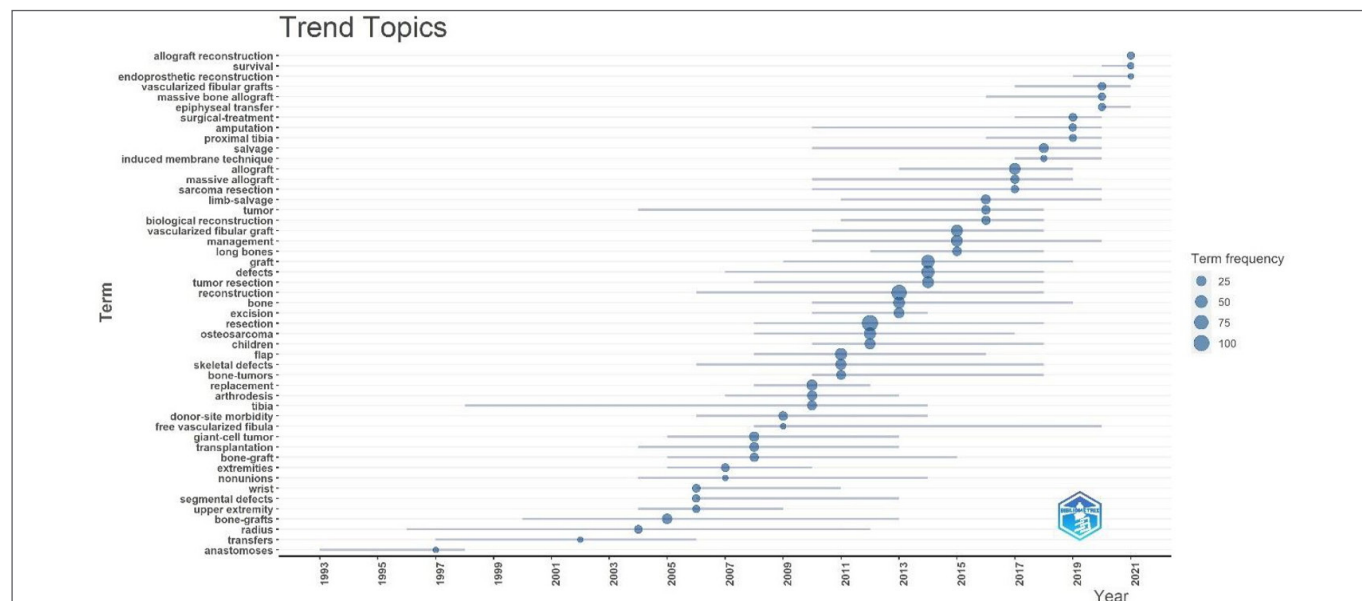


Figure 3a. Trend topics

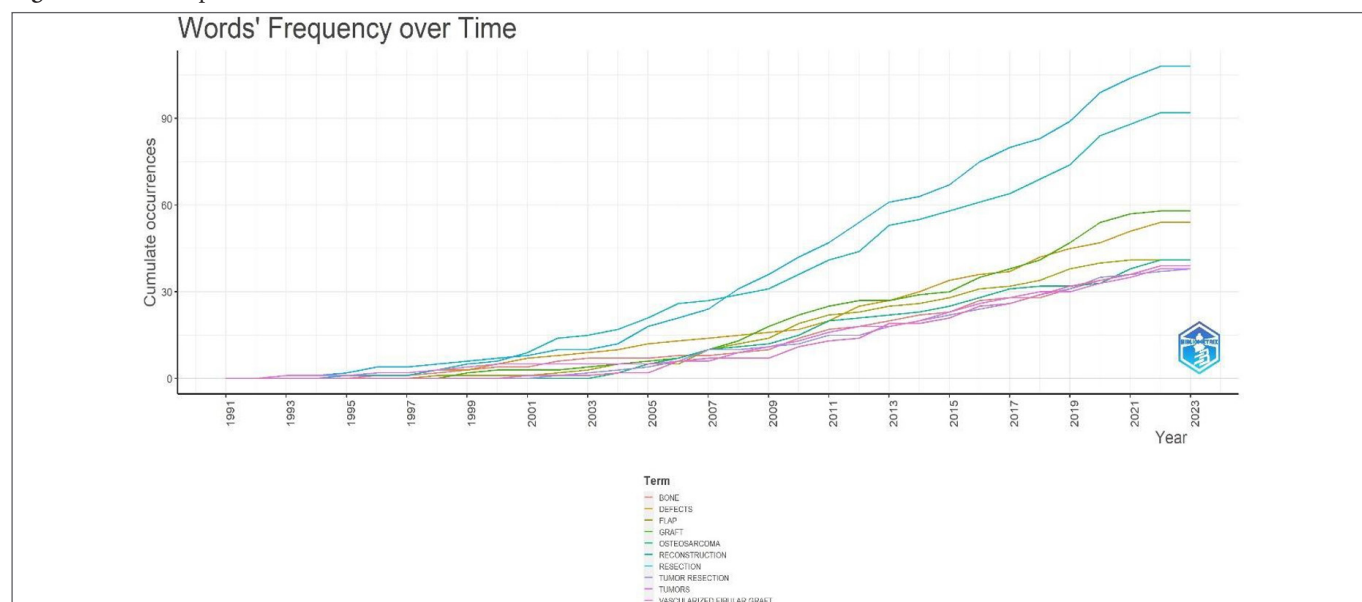


Figure 3b. Word's frequency over time

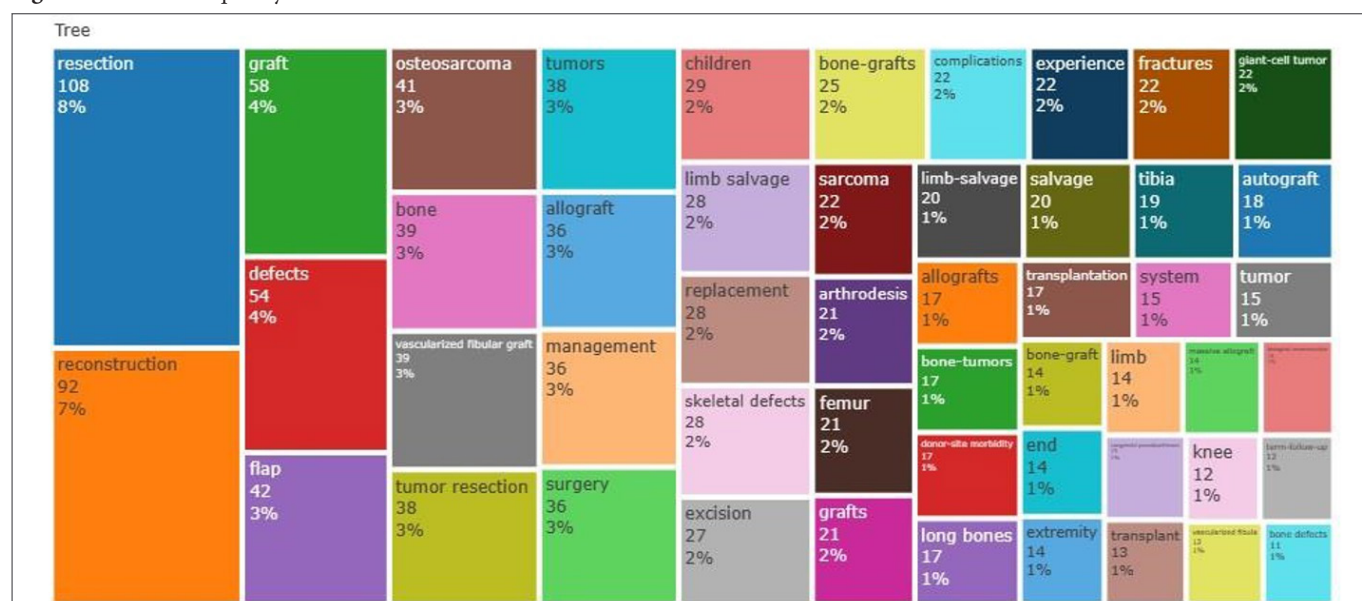


Figure 3c. Keyword frequency tree

Using VOSviewer, we produced two visual network maps for co-citation among institutions and countries (**Figure 4** and **Figure 5**). The network of co-citations throughout institutions and countries is represented by each colors. An item is more commonly co-referenced or cited if the circle is larger.

Among 531 institutions, 39 of them had occurred a minimum of three times. There were 39 items, 7 clusters, and 203 links, and the total link strength was 355.

Among 54 countries, 26 of them had occurred a minimum of three times. There were 26 items, five clusters, and 198 links, and the total link strength was 1537.

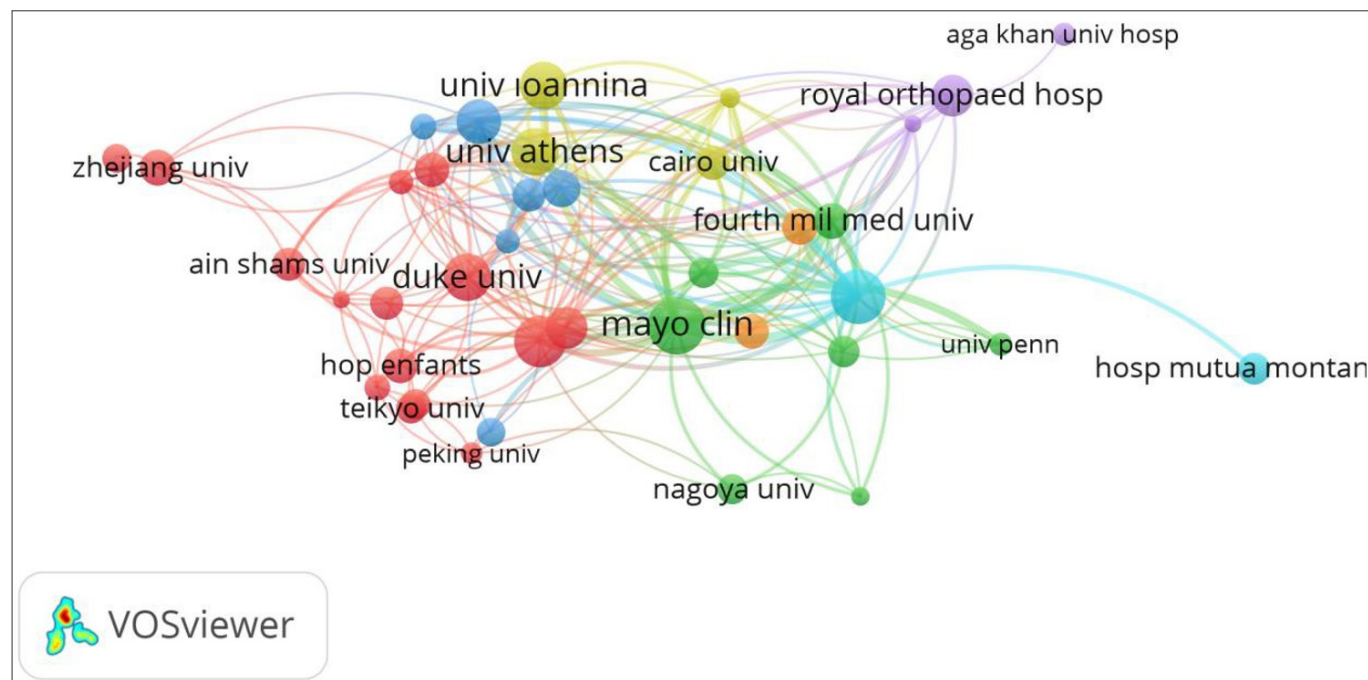


Figure 4. Citation analysis between institutions

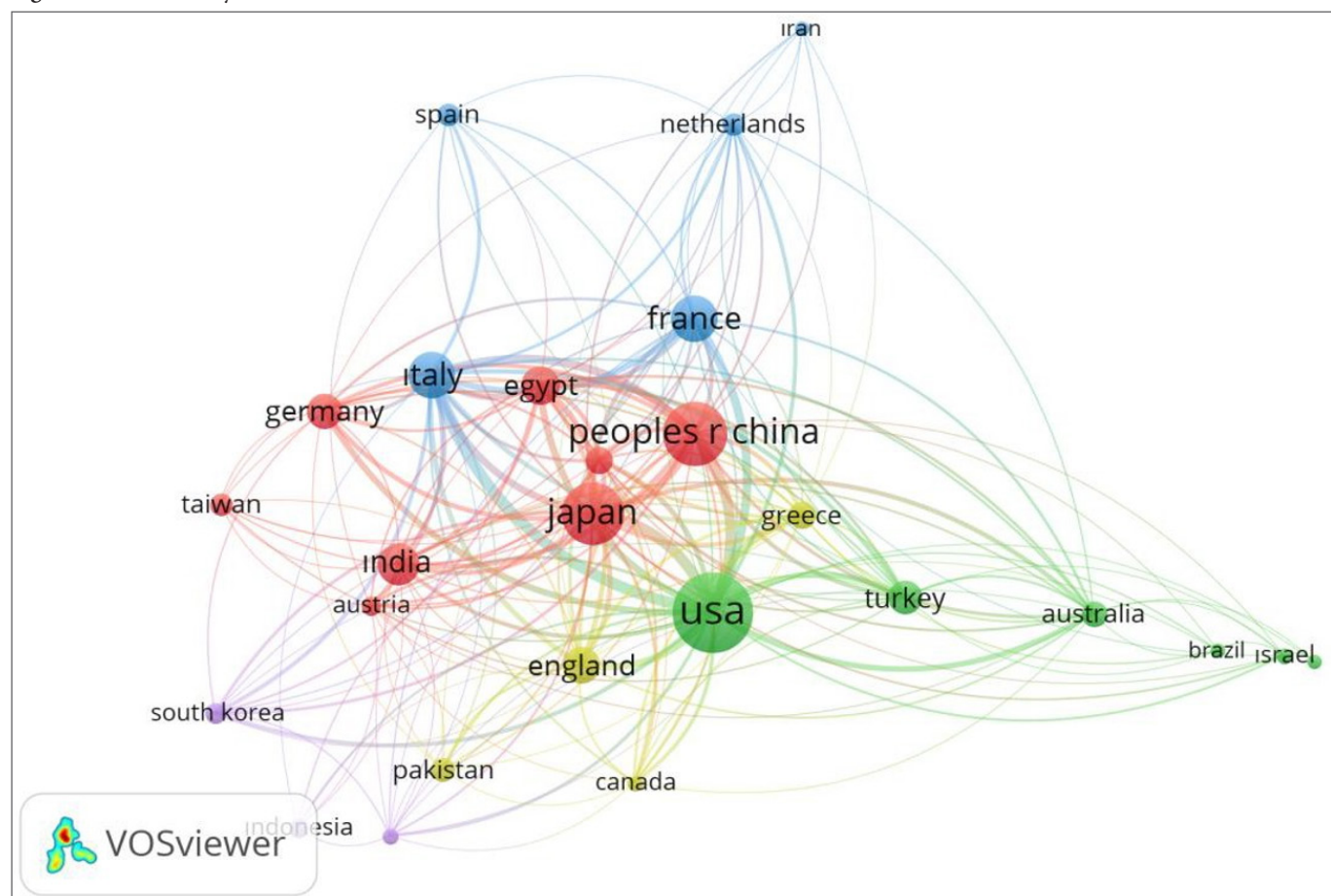


Figure 5. Citation analysis between countries

DISCUSSION

In this study, a comprehensive bibliometric analysis of the literature on VFG was conducted using the WoS database. This is the first bibliometric analysis of the literature on VFG. For this reason, it contains some guiding information for future studies on this subject. This bibliometric analysis carried out as part of this study's design demonstrated a non-linear behavior in the amount of citations and publications received by articles published in VFG. The first article on VFG in WoS database was published in 1986. The publications showed an overall rising tendency, with minor downward variations in a few years. The number of articles has been trending upward since 2005. With 35 articles (7.442%), 2021 has the most publications overall. Every year since 2013, at least 15 publications have been released. Although inconsistent, the annual number of citations for VFG papers has never been lower than 100 since 2005.

A total of 51 countries contributed to publications on VFG between 1986 and 2022. This shows that the topic of VFG has attracted global interest. Although publications were frequently published from developed countries such as the USA, Japan, and European countries, developing countries (such as Egypt, Turkey, and Pakistan) also contributed to the VFG topic.

The USA was identified as the global leader in terms of the number of publications ($n=91$, 21,163%), followed by Japan ($n=58$, 13,488%) and China ($n=56$, 13,023%). From 1986 to 2022, the USA contributed 91 articles and 2162 citations to the VFG, with 23.76 citations per publication and an h-index of 29. Japan contributed 58 articles and 1145 citations to the VFG during the same period, with an h-index of 22 and 19.74 citations per publication. This finding shows that the USA is the leading country in VFG publications in terms of both numbers of publications and citations. In addition, our country citation analysis results show that there is collaboration between countries with the most publications. The authors with the most VFG publications were connected to American academic centers. With 32 publications, the Mayo Clinic in the USA was the most productive affiliation on VFG research. With 11 publications, Sapporo Medical University in Japan came in second, ahead of Duke University in the USA ($n=10$), the University of Pennsylvania ($n=10$), and the University of California, Davis (UC Davis, UCD, or Davis) in the USA ($n=9$). Our inter-institutional citation analysis showed that these institutions were also the institutions where the most cited publications were published. There were also links between institutions in the same color groups regarding attribution of each other.

An article's impact is determined by the number of citations. A high-quality paper is likely to receive more citations, as is generally agreed upon, but determining the paper's quality can be difficult. While this is true, poorly designed research can still be cited in manuscripts. While this is true, poorly designed research can also be cited by other authors.²²

This study analyzed the most cited articles in VFG and found that most of them were from the field of clinical trials, and surgery (orthopedics/plastic surgery). Our current analysis showed that VFG application studies on surgical technique, Limb salvage and tumor received more citations. According to Tahamtan et al., there are a number of variables that might affect the frequency of citations, and they divided these variables into three categories: "Article- related factors," "Author-related factors," and "Journal-related factors." That is why we investigated the journals that publish the most publications on this topic and their impact factors in our study. These journals may also give ideas to authors who plan to publish articles on VFG.²³

When examining the literature for research, keywords are a crucial tool that can be used in place of phrases and sentences. In fact, keywords frequently offer more relevant information.²⁴ Many previously published bibliometric analyses have included information about keywords.²⁵⁻²⁷ We conducted a detailed analysis of these keywords using the Biblioshiny program. We examined the mostly selected keywords by year and the most frequently used keywords in a very detailed way. Three distinct periods were separated from the life span in order to calculate the frequency of keywords throughout time. The term "resection" was used in the most research ($n=108$). These studies also received the most citations after they were published. The majority of articles containing this term were published after 2000s. The second most common term over the past 20 years has consistently been "reconstruction," and it is also the most utilized keyword. 'Graft', 'defects', 'flap', 'osteosarcoma', 'bone', 'vascularized fibular graft', 'tumor resection', 'management', 'allograft', 'children', and 'replacement' are other noteworthy keywords in terms of their frequency of occurrence during the last ten years.

In our study, VFG-related publications were most commonly published in surgery (63.023%) and orthopedics (52.326%). Specific to these fields, tumor and surgical techniques were predominant in this publications. Large tumor resection flaws provide a challenge for skeletal reconstruction. Free VFG gives the chance for quick autograft implantation in extremities wounded by adjuvant radiation or chemotherapy. Despite the high likelihood of complications, free VFG reconstruction provides a durable solution for treating

significant skeletal abnormalities following tumor removal without raising the risk of amputation, local recurrence, or metastasis.^{28,29} In connection with the results of these studies, the effectiveness of this method in the treatment of tumors in the field of orthopedics is an important keyword. the results of the keyword analysis in our study also prove this.

Limitations

Further research might alleviate some of the shortcomings of this study. A considerable discussion of the content coverage of VFG publications, for instance, was not included in the study because it concentrated primarily on the presentation and visualization of bibliometric and scientometric indicators. Consequently, a scoping review that considers the conceptualization and definition of the VFG topic could be a good starting point for future research. The fact that this study does not provide information regarding how the literature on VFG has evolved is another disadvantage. While bibliometric and scientometric indicators can be employed for these goals, they are insufficient for judging the caliber of knowledge generated. One database was only searched, which is another drawback. As a result, it doesn't encompass the entirety of the VFG literature.

CONCLUSION

Although the VFG surgical technique is a featured and popular technique in orthopedic surgery, the number of publications reported for VFG remains insufficient in the orthopedic and surgical literature. Future studies should consider including more publications and database outputs (such as Pubmed/Scopus). In addition, the inclusion of other outcomes, including the content of publications, would be helpful for researchers.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study is an open data bibliometric study, does not contain human or animal material, and does not require ethics committee approval.

Informed Consent: The study is an open data bibliometric study, does not require informed consent.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version.

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